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Description

Device for the generation of vortices and method for operating the device

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The invention relates to a device for the generation and/or destruction of vortices in a flow medium, said device comprising one or more profiles arranged in a flow duct and provided for flow around by the flow

10 medium. It relates, further, to a method especially suitable for operating the device.

The controlled generation or destruction of vortices plays an important part in many flow-related

15 applications. Since vortices contain rotational energy and can therefore both absorb and discharge energy, they are used for the controlled transmission of energy from a flow-around profile to the flow medium or into a boundary layer or for the exchange of energy, in

20 particular including heat, or of substances between different regions of a flow.

For the efficient transport of a flow medium, for example, systems are used consisting of stationary

25 vortex generators which transmit energy to the flow medium as a result of the generation of vortices. In this case, it is desirable to keep the pressure loss which the flow medium experiences along the system consisting of vortex generators as low as possible. In

30 particular, the mean mass flow with respect to the pressure loss is to be as high as possible.

Owing to the use of vortex generators in the flow duct, velocity fluctuations can also be imparted to a flow

35 medium. Such velocity fluctuations, which are generated, for example, by means of shockwaves occurring at vortex generators, considerably increase

both heat exchange and mass transfer in the flow medium transversely to the flow

direction. By virtue of the targeted mounting of vortex
generators in the flow duct, an intensified cooling
action of the flow on components subjected to
especially high thermal load can thus be achieved. In
5   this case, the vortex generators should be positioned
and dimensioned in such a way that the heat
transmission coefficient in relation to the pressure
loss which the flow medium experiences along the system
consisting of vortex generators is as high as possible.
10   Thus, for example due to the use of a system consisting
of vortex generators in a gas turbine, cooling air can
be saved both in the region of the combustion chamber
and in the region of the turbine blades, and
consequently, with at the same time the efficiency of
15   the gas turbine being increased, its NOx emissions can
be lowered.

The intensified mass transfer transversely to the flow
direction in a flow medium with velocity fluctuations
20   may be utilized for the intensified mixing of the flow
medium. For example, owing to the especially thorough
mixing of fuel gas and air in a gas turbine plant, a
complete combustion of the fuel gas can be achieved and
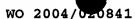therefore its NOx emissions can be lowered.

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The diversity of technical applications of vortex
generators or vortex destroyers means that there is
great interest in the theoretical calculation of the
occurrence and development of vortices. They are
30   necessary, in particular, in order to configure the
shape and positioning of vortex generators and vortex
destroyers optimally in terms of their action on a flow
medium. The calculation of turbulent flows is
conventionally carried out either explicitly by solving
35   the Navier-Stokes equation of the problem, although
this is a procedure which is too complex and involves
too high an outlay, above all in the case of three-

dimensional applications, or else via corresponding models of the classic hydrofoil theory.

Within the framework of the classic hydrofoil theory,
5 admittedly, turbulent flows at components which are rigid, that is to say with a passive flow around and

not accelerated, can be described. However, with components which are active, that is to say moved in an accelerated manner, the classic hydrofoil theory falls down. To be precise, it presupposes the smooth flow-off
5 of the flow medium at the trailing edge of the flow-around profile, what is known as the Kutta condition, and also a finite onflow velocity and a quasistatic linear treatment. A breakaway of the flow from the flow-around profile and a rolling-up of vortices which
10 occur, such as takes place in the case of non-stationary flow processes on profiles moved in an accelerated manner, cannot be treated within the framework of the theory. Where technical applications are concerned, therefore, vortex generators with a
15 passive flow around are normally used, which can be described by means of classic aerodynamics. However, vortex generators with a passive flow around have comparatively high dynamic resistances. If they are placed in a flow duct, this therefore results in an
20 undesirably high pressure drop in the flow medium.

The object on which the invention is based is, therefore, to specify a device for the generation of vortices in a flow medium of the abovementioned type,
25 by means of which, along with as low a pressure drop as possible, vortices can be generated in a flow medium in an especially simple way and at an especially low outlay in energy terms. Furthermore, a method especially suitable for operating the device is to be
30 specified.

As regards the device, this object is achieved, according to the invention, in that the device comprises one or more profiles arranged in a flow duct
35 and provided for flow around by the flow medium, the profiles being provided with a mechanical, electro-magnetic or electrohydraulic drive for a periodic
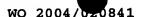
movement in relation to the flow medium with an angular
frequency ω.

What may be provided as "profiles" in this context are
5   any desired suitably dimensioned and contoured fittings
in the flow duct, which, particularly in terms of their
shape, are adapted to the

flow conditions expected as a consequence of design in the flow duct.

The invention in this case proceeds from the
5   consideration that, for a high efficiency of the vortex generator, the mean throughput of flow medium in relation to its pressure loss along the flow duct should be as high as possible. In order to keep the pressure loss low, the transmission of energy from the
10   vortex generator to the flow medium should consistently be improved. A better transmission of energy can be achieved in that the energy content of the generated vortex is increased. As has become clear, higher energy contents can be achieved by means of active, that is to
15   say accelerated vortex generators, both in laminar and in turbulent flows, in that the vortex is accelerated before its breakaway from the profile of the vortex generator. For especially high efficiency, therefore, vortex generators should be moved in an accelerated
20   manner in relation to the flow duct. A uniform vortex generation which satisfies these requirements can in this case be achieved in an especially simple way by means of a periodic movement of the vortex generator.

25   In order to understand the processes at periodically moved vortex generators, use can be made of the knowledge that a vortex generated by such a vortex generator and breaking away can be described effectively by means of a spatially limited vortex
30   having a rigid core, what is known as a "finite edge vortex". Such a vortex, immediately after its formation on the trailing edge of the flow-around profile, is filled up by flow medium flowing in toward its center, up to the rest of its progression in time, as a radius
35   a which is assumed to be constant. As a result, the vortex is set in rotation, and its rotational velocity increases further during the subsequent "adhesion phase". In this case, the vortex experiences a net

throughflow by flow medium, and the component of the
flow from the direction of the profile trailing

edge increases up to a maximum value. The vortex, after
reaching its stable size, adheres to the profile until
this maximum value is reached, and then breaks away.

5   While the vortex is still adhering to the profile, its
rotation induces a tangential flow along the profile
surface, what may be referred to as the "sheathing
flow". The aerodynamic interaction of the sheathing
flow with the onflow of the flow medium onto the
10   profile generates an orthogonal pair of forces,
propulsion and resistance. Depending on which of the
two forces predominates, the character of the
interaction between flow medium and profile changes.
Thus, for example in the case of a movement of the
15   profile with a comparatively high frequency, the
propulsion character of the interaction predominates
and energy is transmitted from the vortex generator to
the flow medium, whereas, in the case of the movement
with low frequency, the resistance character
20   predominates and energy is transferred from the flow
medium to the vortex generator.

These findings within the framework of what is known as
the "finite edge vortex model" are utilized when new
25   characteristic quantities are employed. What is
suitable as a characteristic quantity describing the
propulsion characteristic or resistance characteristic
of the flow is the ratio of the flow velocity averaged
over a movement period of the profile with respect to
30   the mean cross section of the profile to the maximum
flow velocity at the profile trailing edge. If this
quantity $f: = v_m/v_{max}$ is between 0.2 and 0.5, the flow
has a propulsion character. By contrast, if f is higher
than 0.5, it has a resistance character.
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The Reynolds' number of the maximum edge flow around,
the reduced frequency and the Strouhal number can be
used as further important characteristic quantities.

The Reynolds' number of the maximum edge flow around is
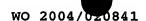in this case defined

as the product of the maximum flow velocity at the
profile trailing edge and the elongation of the flow-
around profile, divided by the kinematic viscosity of
the flow medium, the reduced frequency is defined as

5   the product of the angular frequency of the periodic
movement and elongation of the flow-around profile,
divided by the flow velocity averaged over a movement
period of the profile with respect to the mean cross
section of the profile, and the Strouhal number is

10 defined as the frequency of the periodic movement and
the elongation of the flow-around profile, divided by
the flow velocity averaged over the movement period of
the profile with respect to the mean cross section of
the profile. Said characteristic quantities are used

15 instead of the external constant profile onflow
velocity employed in classic aerodynamics and permit
substantially more differentiated and more realistic
characterization of the resulting flow.

20 Advantageously, the shape, number and size of the
profiles are selected such that, when the vortex
generator is operating, the quotient of the flow
velocity averaged over the movement period of the
profile with respect to the mean cross section of the

25 profile and the maximum flow velocity at the profile
trailing edge has a predetermined value. In particular,
this value may be selected such that, depending on the
type of technical application, a flow with a resistance
character or with a propulsion character is obtained as

30 a result.

Depending on the technical task to be fulfilled by the
vortex generator, different types of periodic movements
of the profiles are conceivable and beneficial.

35 Advantageous basic forms of periodic movements are
periodic displacements of the profiles perpendicularly
to the flow direction of the flow medium, rotations of

the profiles about an axis of rotation perpendicularly to the flow direction in the manner of a pivoting through an angle φ, and the rotation of pairs of profiles with the same angular frequency ω and the same phase about their respective

axis of rotation, the axes of rotation being oriented antiparallel to one another, and also periodic displacements of the profiles parallel to the flow direction of the flow medium.
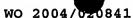
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To improve the efficiency of the vortex generator and for adapting it optimally to its technical task, the profiles, if appropriate, execute combinations of said basic forms of the periodic movements. Advantageously,

10   the periodic movement of the profile may consist, in particular, of a combination of a displacement of the profile in relation to the flow duct and of a rotation of the profile about an axis of rotation.

15   In many applications, it is beneficial to destroy a generated vortex again after it has covered a particular distance in the flow duct. This is the case, for example, when the residual wake energy of the vortex is to be utilized as fully as possible. In such

20   a case, the vortex generator is advantageously followed on the flow medium side by a device for the destruction of vortices.

Since, in the case of low drive power, active vortex

25   generators are capable of transmitting energy and substances in an especially efficient way, they may be used in a multiplicity of technical sectors. In the conveyance of a flow medium through a flow duct or a pipeline, the aim is, for example, to achieve as high a

30   mass flow as possible, with at the same time a low pressure loss in the flow medium. However, the desired increase in the flow velocity of the flow medium, along with a low pressure loss, can be achieved precisely with the aid of an active vortex generator. A device

35   for the active generation of vortices is therefore advantageously arranged in the flow duct of a conveying zone, said device comprising a number of vortex

generators which execute a periodic movement with the same angular frequency ω and the same phase.

Alternatively to this, the phase of the vortex generators may also be opposed, that is to say displaced at 180 degrees with respect to one another.

5   A further important use of active vortex generators is to increase the efficiency of cascade flows. Cascade flows are employed in order to maximize the mean efficiency of an axial cascade, with at the same time as low a pressure loss as possible. For this purpose,

10   for example, guide vanes precede the moving blades of a gas turbine on the flow medium side. For a further increase in the cascade efficiency, the axial cascade is advantageously preceded on the flow medium side by a device for the active generation of vortices which

15   device comprises a number of profiles which execute a periodic movement with the same angular frequency ω and the same phase. In particular, periodic flow pulses can thereby be generated, which are optimally coordinated in their period and length with the likewise periodic

20   actual cascade flow. Furthermore, the "clocking effect", as it is known, which increases the efficiency of the cascade and is not yet fully understood theoretically may be utilized, this coming under consideration when individual cascades moved in

25   relation to one another interact with one another.

Velocity fluctuations imparted to a flow medium can be utilized for the especially efficient cooling of components subjected to high thermal load. Such

30   velocity fluctuations can be generated in an especially efficient way by means of active vortex generators and considerably increase both the heat exchange and the mass transfer in the flow medium transversely to the flow direction. Thus, by virtue of the targeted

35   mounting of active vortex generators in the flow duct, an efficient cooling of components subjected to particularly high thermal load can be achieved. For

this purpose, a cooling device advantageously comprises a flow duct, a cooling stream conducted through the flow duct and a device which is arranged within the flow duct and which has

one or more periodically moved profiles for the active generation of vortices.

Velocity fluctuations imparted to a flow medium also
5 intensify the mass transfer transversely to the flow direction. This effect can be utilized in a controlled manner for the intensified mixing of a flow medium. Especially high mixing quality, with at the same time a low pressure loss, can be achieved in that active
10 vortex generators are used in order to generate the velocity fluctuations. It is usually desirable for the velocity fluctuations imparted to the flow medium by generated vortices to be destroyed again after mixing is concluded. A mixing zone therefore advantageously
15 comprises a device for the active generation of vortices which is followed on the flow medium side by a device for the destruction of vortices.

By means of an active vortex generator, substance and
20 energy streams can be generated and/or intensified in an especially efficient way, with at the same time a low pressure drop within the flow medium, for example during the mixing of fuel gas and air in a compressor or during the cooling of the component subjected to
25 especially high thermal load. The active vortex generator is therefore advantageously used in a gas turbine.

As regards the method, said object is achieved in that
30 one or more profiles arranged in a flow duct and provided for flow around by a flow medium are moved periodically with the angular frequency ω by means of an external drive.

35 New findings within the framework of what is known as the "finite edge vortex model" show how it is possible in a controlled manner to influence the imparting of a

resistance character or propulsion character of a flow
around moved profiles, that is to say the direction of
energy transmission

between profile and flow medium. An important
characteristic quantity within this model is the
quotient of the flow velocity averaged over a movement
period of the profile with respect to the mean cross
5   section of the profile and the maximum flow velocity at
the profile trailing edge. Advantageously, the
direction of energy transmission between moved profile
and flow medium is set by this quotient. Alternatively,
the direction of energy transmission between profile
10   and flow medium can also be set via the product of the
maximum flow velocity at the profile trailing edge and
of the elongation of the flow-around profile, divided
by the kinematic viscosity of the flow medium.

15   In many technical applications, disadvantages may arise
when, as the flow progresses further, generated
vortices bring about a comparatively high degree of
turbulence of the flow. Advantageously, therefore, the
generated vortices are completely or partially
20   destroyed again downstream of the position in the flow
duct at which they were generated.

As calculations within the framework of the "finite
edge vortex model" have yielded, substance and energy
25   streams can be generated and/or intensified by the use
of active vortex generators especially efficiently and
with a comparatively low pressure drop within the flow
medium. The method for the generation of vortices by
means of active vortex generators is therefore
30   especially suitable for various technical applications,
for example for the transportation or mixing of flow
media, for increasing the efficiency of cascade flows
and for the cooling of components subjected to
especially high thermal load.

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The advantages achieved by means of the invention are,
in particular, that vortices can be generated at a
comparatively low outlay in energy terms as a result of

the use, now provided, of periodically moved vortex generators. The

periodic movement of the profiles can in this case be implemented in a comparative simple way in technical terms by the use of an external mechanical, electrical or electrohydraulic drive. When active, in contrast to
5 passive, vortex generators are used, substance and energy streams can be generated and/or effectively intensified in a flow medium, with at the same time especially low pressure losses within the flow medium. The low pressure loss can in this case be attributed to
10 the fact that active vortex generators are characterized by very low resistances.

On account of the beneficial technical properties mentioned, active vortex generators have a multiplicity
15 of application possibilities. Due to the use of active vortex generators, for example, the cascade flow in the compressor of a gas turbine can be configured more efficiently and the clocking effect can be utilized to an increased extent. The cooling of components
20 subjected to thermal load can also be improved by means of active vortex generators, and therefore cooling air can be saved. Furthermore, owing to the use of active vortex generators, a more thorough mixing of, for example, fuel gas and air prior to combustion, for the
25 reduction of NOx emissions, is possible. An increase in the efficiency of the gas turbine and a reduction in its emissions can thus be achieved at a comparatively low outlay in technical terms.

30 An exemplary embodiment of the invention is explained in more detail with reference to a drawing in which:

fig. 1   shows a profile around which a flow medium flows and at the trailing edge of which a
35   vortex is generated, .

fig. 2   shows various versions of a device comprising one or more profiles for the generation of vortices in a flow medium,

fig. 3   shows a zone for the transport of a flow medium, said zone comprising a device for the generation of vortices,

5   fig. 4   shows a further zone for the transport of a flow medium,

fig. 5   shows a cylindrical section, unrolled into the plane, through a guide-vane and moving-blade
10   row of a gas turbine, said row being preceded by a device for the generation of vortices,

fig. 6   shows a device for the cooling of components subjected to high thermal load, and

15

fig. 7   shows a device for the mixing of a flow medium.

Identical parts are given the same reference symbols in all the figures.

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Fig. 1 shows a device for the generation of vortices by means of a profile 1 around which a flow medium S flows and which may be located, for example, in a flow duct, not illustrated in fig. 1. The flow direction of the
25 flow medium S is indicated by the arrows 2 in a stream-lined manner. The profile 1 can be moved by means of an external drive, not illustrated in fig. 1, the movement generally being composed of a displacement of the profile 1 over a distance x and of a rotation of the
30 profile 1 through an angle φ. The movement takes place periodically at an angular frequency ω. During the movement of the profile 1 in relation to the flow medium S, two vortices are formed at the trailing edge 4 of the profile 1 during each period of the movement,
35 grow immediately after their formation, adhere to the trailing edge 4 for a short time and then break away.

The vortices which are formed can be described comparatively realistically with the aid of the "finite edge vortex model". Within the framework of this model, vortices formed at the trailing edge 4 of the profile 1

5   are not described as ideal vortices, but instead as vortices with a sharply defined radius and with a rigidly rotating core. Fig. 1 illustrates such a "finite edge vortex", as it is known, 6. The finite edge vortex 6, immediately after being formed at the

10   trailing edge 4 of the flow-around profile 1, is filled up to its radius a by flow medium S flowing toward its center and is set in rotation. Its rotational velocity increases further during the subsequent "adhesion phase", where the finite edge vortex 6 experiences a

15   net throughflow by flow medium S, and the component of the flow from the direction of the trailing edge 4 increases up to a maximum value. The finite edge vortex 6 breaks away from the trailing edge 4 at the moment at which this maximum value is reached. During the

20   adhesion phase, the rotation of the finite edge vortex 6 induces a tangential flow along the profile surface, what may be referred to as the "sheathed flow". The sheathed flow comes into interaction with the onflowing flow medium S, an orthogonal pair of forces, the

25   propulsion V, indicated by the arrow 8, and the resistance W, indicated by the arrow 10, being obtained.

The character of the interaction between flow medium S

30   and profile 1 depends critically on which of the two forces predominates. As both theoretical investigations within the framework of the "finite edge vortex model" and experimental findings show, in the event of a movement of the profile 1 with relatively high angular

35   frequency ω, the propulsion character of the interaction predominates and energy is transmitted from the profile 1 to the flow medium S. By contrast, in the event of a movement with a low angular frequency ω, its resistance character predominates and energy

transmission takes place in reverse from the flow medium S to the profile 1.

In contrast to the classic hydrofoil theory, the
relatively simple "finite edge vortex model" makes it
possible to describe the flow around a profile 1 moved
in an accelerated manner. It thus makes possible the
5   controlled use of active vortex generators, that is to
say those which comprise a number of profiles 1 moved
in an accelerated manner. In contrast to a rigid
profile, a profile 1 moved in an accelerated manner has
considerably lower dynamic resistance. In other words:
10   a moved profile 1 gives rise to a considerably lower
pressure loss within the flow medium S than a rigid
profile. It can thus be used, for example, for the
efficient transportation or mixing of flow media S, a
comparatively high throughput of flow medium, with at
15   the same time a low pressure loss, being achieved on
account of the low dynamic resistance of the profile 1.

Various types of periodic movement of the profile 1 may
be envisaged. Fig. 2 shows various possibilities for
20   the periodic movement of the profile 1 in relation to
the flow medium S. The flow medium S flows through a
flow duct 12 in the direction indicated by the arrow 2.
As illustrated in fig. 2a, a finite edge vortex 6 can
be generated in the flow medium S, in that a profile 1
25   is displaced periodically over a distance x
perpendicularly to the flow direction, that is to say
executes a pure translational movement.

Fig. 2b shows another possibility for the periodic
30   movement of the profile 1, in which the profile 1
executes a pure rotational movement about an axis of
rotation 14 perpendicularly to the flow direction
through an angle φ. In technical applications, it is
advantageous under some circumstances to use
35   combinations of translational and rotational movements.
As shown in fig. 2c, a plurality of profiles 1 may also
be employed in order to generate vortices. By means of
a configuration, as in fig. 2c, in which a pair of

profiles 1 oscillates in countersynchronism or in synchronism at the exit of a further flow duct 16 arranged in the flow duct 12, for example,

two flow media flowing in the flow duct 12 and in the
further flow duct 16 can be efficiently intermixed
and/or transported. In such an arrangement, in each
oscillation period of the profile 1, two pairs of
5 finite edge vortices 6 break away from the profile
trailing edges 4 and form what is known as a wake 18 in
the flow duct 12. Fig. 2d shows a device for the
generation of finite edge vortices 6 without
periodically moved components. Here again, a further
10 flow duct 16, through which a flow medium S flows, is
arranged within a flow duct 12. However, the flow
medium S flows through the further flow duct 16 with a
periodic variation of its mass flow m. At the exit 22
of the further flow duct, in each period a pair of
15 finite edge vortices 6 is formed, which breaks away
after the adhesion phase and forms a wake 18 in the
flow duct 12.

As calculations within the framework of the finite edge
20 vortex model have yielded, the profiles 1 should follow
certain rules in their shape and dimensioning. In
particular, the profiles 1 should have a sharp trailing
edge which is as long as possible, so that the maximum
flow velocity at the trailing edge 4 is as high as
25 possible and the finite edge vortex 6 which occurs has
a comparatively small radius. A harmonic oscillation
form of the profile 1 is not desirable in every case,
in order to achieve a long adhesion phase of the finite
edge vortex 6 and high propulsion. Depending on the
30 field of use of the vortex generator, the oscillation
frequency and amplitude, the position of the axis of
rotation 14 during a rotation and the general shape of
the profile 1 must be optimized in such a way that
optimal energy transmission between profile 1 and flow
35 medium S takes place by means of as low an external
drive as possible and with a low pressure drop.

Owing to the favorable properties of the finite edge

vortices 6, their generation can be utilized, for
example, for the transportation

of a flow medium. Fig. 3 shows a zone for the transport
of a flow medium, said zone comprising a device for the
generation of finite edge vortices 6. As can be seen in
fig. 3a, a plurality of profiles 1, for example three,
5   which execute a periodic movement in synchronism are
arranged in a flow duct 12. The periodic movement may
consist of a rotation through the angle φ about an axis
of rotation 14 or else of a combination of the rotation
with a periodic displacement of the profile 1. In each
10 case two finite edge vortices 6 occur in each period at
the respective trailing edges 4 of the profiles 1
oscillating in synchronism. The energy transmitted to
the flow medium S by the profiles 1 as a result of
vortex formation is utilized for the transport of the
15 flow medium S through the flow duct 12. If the profiles
1 execute a pure rotational movement, they can be
driven by means of the external drive illustrated in
fig. 3b. For this purpose, the profiles 1 are mounted
in the region of their trailing edge 4 on a connecting
20 rod 23 which is connected to a crank drive 26 via an
articulated lever 24. When the vortex generator is
operating, the crank drive 26 moves the connecting rod
23 up and down and thus drives the rotation of the
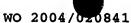profiles 1 about their respective axis of rotation 14.

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If, by contrast, the profiles 1 execute a combination
of a translational and rotational movement, they can be
driven by means of the external drive illustrated in
fig. 3c. For this purpose, the drive device illustrated
30 comprises a connecting rod 23, on which the profile or
profiles 1 are mounted in their rear region, and also a
further connecting rod 30 which connects the profiles 1
to one another in their front region. When the device
is operating, both the connecting rod 23 and the
35 further connecting rod 30 execute a periodic movement
in the upward and downward direction which is brought
about by an electromagnetic drive 27 and via a further
electromagnetic   drive   28,   respectively.   In

order to achieve a rotation of the profiles 1 about the axis of rotation 14, the electromagnetic

drive 27 and the further electromagnetic drive 28 do not operate in phase. Instead, the electromagnetic drive 27 may have a phase lead of 90 degrees with respect to the further electromagnetic drive 28. The profiles 12 thus execute a combination of a translational movement over the distance x and a rotational movement through the angle φ within the flow duct 12.

Owing to the use of the device illustrated in fig. 3 through a flow duct 12, the flow medium S can be transported especially efficiently through a flow duct 12. To be precise, as calculations within the framework of the "finite edge vortex model" have yielded, the periodic movement of the profiles 1 ensures that energy is transmitted from the profiles 1 to the flow medium S especially efficiently. In particular, the throughput of flow medium S through the flow duct 12 in relation to the pressure loss can thereby be maximized.

For the efficient transport of a flow medium S through a flow duct 12, profiles 1 oscillating in counter-synchronism, such as are illustrated in fig. 4, are also suitable. Fig. 4a shows an alternative zone for the efficient transportation of a flow medium S. Within a flow duct 12, a further flow duct 16 is arranged, for example concentrically, at the exit of which is arranged a pair of profiles 1 which in each case execute periodic rotational movements. For this purpose, they oscillate in countersynchronism, that is to say with a phase displacement of 180 degrees, and at their trailing edge 4 generate per period in each case two finite edge vortices 6 which, after their adhesion phase, break away from the trailing edges 4 and generate a wake 18 in the flow duct 12. In technical applications, it may be beneficial, for example for utilizing the residual wake energy, to destroy the broken-away vortices completely or partially again. For this purpose, the profiles 1 may be followed on the

flow medium side by a vortex destroyer, not illustrated
in fig. 4.

Fig. 4b shows a drive suitable for operating the vortex
generator illustrated in fig. 4a. For this purpose, the
drive comprises an electromagnetic drive 27, which
activates a hydraulically operating working cylinder
5 32, and two articulated levers 24 which are mounted on
the profiles 1 and, via their movement caused by the
working cylinder 32, bring about a rotation of the
profiles 1 about their respective axis of rotation 14.

10 In addition to the efficient transport of a flow
medium, active vortex generators may also be employed
in various other technical fields. Fig. 5 illustrates
the principle of use of active vortex generators for
increasing the efficiency of a cascade flow. For this
15 purpose, an axial cascade, illustrated in fig. 5a by a
cylindrical section unrolled into the plane, is
preceded by a number of active vortex generators.
Fig. 5a shows a guide-vane row 33 of a gas turbine,
which comprises a number of guide vanes 34 and which is
20 followed on the flow medium side by a moving-blade row
35 comprising a number of moving blades 36. The guide-
vane row 34 and the moving-blade row 36 are arranged in
the flow duct, not illustrated in any more detail,
through which the flow medium S flows in the direction
25 indicated by the arrow 2. The guide-vane row 34 is
preceded on the flow medium side by a vortex generator
row 38 which comprises a number of profiles 1. The
profiles 1 are designed in such a way that they are
rotated about their respective axis of rotation 14 by
30 an external drive. During a full oscillation period of
the profiles 1, each profile 1 generates at its
trailing edge 4 two finite edge vortices 6 which break
away after the adhesion phase and move through the flow
duct on the path indicated by the arrow 40. The finite
35 edge vortices 6 move on their path around the guide
vanes 34 due to the energy transmitted to them by the
profiles 1 and impinge onto the moving blades 36 which
follow the guide vanes on the flow medium side and to
which said vortices discharge their energy. The flow

pulses thereby generated increase the efficiency of the
cascade flow, inter alia due to the utilization of the
not yet fully understood "clocking effect" as it is
known, an effect which is based on the aerodynamic
5   interaction of various cascades with one another and
which comes into force when the cascades assume an
exactly defined position with respect to one another.
The clocking effect already utilized in the positioning
of the guide vanes 34 in relation to the moving blades
10 36 is further intensified by the profiles 1 as a result
of the generation of flow pulses generated so as to
match the movement of the moving blades 36 in duration
and frequency. Said effect measurably increases the
efficiency of the cascade flow and can thus contribute
15 to the increase in efficiency of, for example, a gas
turbine and consequently to the lowering of its
emissions.

Fig. 5b shows a possible drive for the profiles 1
20 illustrated in Fig. 5a. The profiles 1 are mounted on a
common connecting rod 23 in the region of their
trailing edge 4 and are supported rotatably about their
respective axis of rotation 14 in their front region on
a further connecting rod 30. When the vortex generator
25 is operating, the electromagnetic drive 27 moves the
connecting rod 23 upward or downward via the
hydraulically operating working cylinder 32. This
results in an in-phase rotation of the profiles 1 about
their respective axis of rotation 14.

30

The heat exchange and mass transfer in a flow medium
transversely to its flow direction can be increased
considerably by means of velocity fluctuations imparted
to the flow medium. Such velocity fluctuations can be
35 imparted especially simply, and with a comparatively
low pressure loss in the flow medium, by the use of
active vortex generators. Fig. 6 shows an arrangement
in which finite edge vortices 6 generated by the
profiles 1 can be utilized for the cooling of

components subjected to especially high thermal load.
For this purpose, a number of profiles 1, for example
three profiles 1, are arranged on a common connecting
rod 23

in a flow duct 12 of, for example, a gas turbine. The connecting rod 23 can be periodically moved upward in the direction indicated by the arrow 42 and subsequently downward again by means of an external
5   drive. The drive of the connecting rod 23 may in this case take place mechanically, as in fig. 6a, or alternatively electromagnetically, as in fig. 6b. When operating, on account of the external drive, the profiles 1 execute a translational movement over the
10 distance x within the flow duct 12 and thereby impart the velocity profile p to the flow medium S. The finite edge vortices 6 occurring at the moved trailing edges 4 of the profiles 1 and breaking away from the profiles 1 impart in turn to the velocity profile p periodic
15 velocity fluctuations which considerably increase the heat exchange transversely to the flow direction and thus contribute to the desired improvement in the cooling of the wall 44. In particular, the improvement in the cooling action of the flow is attributable to
20 the upstream displacement of the laminar/turbulent reversal point of the flow due to the use of the vortex generator. The heat transmission coefficient is thereby markedly increased and the cooling action improved. Thus, with the temperature of the wall 44 remaining the
25 same, flow medium S can be saved or, at the same outlay of flow medium S, an increase in power and efficiency of the gas turbine can be achieved.

The mass transfer transversely to the flow direction,
30 increased as a result of the use of a vortex generator, may also be utilized for the mixing of flow media with one another. For this purpose, as illustrated in fig. 7a, a profile 1, which is moved periodically by means of an external drive, is arranged in a flow duct
35 12 through which a flow medium S flows in the direction of the arrow 2. In this case, as illustrated in fig. 7b, the drive takes place mechanically via a slider crank. During each period, the periodically

moving profile 1 generates two finite edge vortices 4
which occur at its trailing edge 4 and which break away
after the adhesion phase. The turbulences

thereby generated in a controlled manner ensure an
efficient mixing of the flow medium S which may
consist, for example, of a plurality of components,
such as air and fuel gas or light fuel oil and water,
5   which are to be intermixed with one another. Where a
gas turbine is concerned, by virtue of the especially
thorough intermixing of fuel gas and air, a complete
combustion of the fuel gas and consequently a lowering
of the NOx emissions of the gas turbine can be
10   achieved. The profile 1 for the generation of vortices
may be followed on the flow medium side by a profile,
not illustrated in fig. 7, for the destruction of
vortices, if a turbulent flow in the further
progression is not desired.

15

Patent claims

1.   A device for the generation and/or destruction of
vortices in a flow medium (S), said device comprising
5   one or more profiles (1) arranged in a flow duct (12)
and provided for flow around by the flow medium (S),
the profiles (1) being provided with an external drive
for a periodic movement in relation to the flow medium
(S) with an angular frequency ω.
10

2.   The device as claimed in claim 1, the shape and
size of the profiles (1) being selected such that,
during operation, the quotient of the flow velocity
averaged over a movement period of the profile (1) with
15   respect to the mean cross section of the profile (1)
and the maximum flow velocity at the profile trailing
edge (4) has a predetermined value.

3.   The device as claimed in claim 1 or 2, in which
20   the periodic movement provided is a pivoting movement
of the profiles (1) as a result of the rotation of the
profiles (1) about an axis of rotation (14)
perpendicularly to the flow direction of the flow
medium (S) through an angle φ.
25

4.   The device as claimed in claim 3, the flow duct
(12) having arranged in it two profiles (1) which
rotate with the same angular frequency ω and the same
phase about their respective axis of rotation (14), the
30   axes of rotation (14) being oriented antiparallel to
one another.

5.   The device as claimed in claim 1 or 2, in which
the periodic movement consists of a periodic
35   displacement of the profiles (1) perpendicularly to a
flow direction of the flow medium (S).

6.   The device as claimed in claim 1 or 2, in which the periodic movement consists of a periodic displacement of the profiles (1) parallel to the flow direction of the flow medium (S).

7.   The device as claimed in claim 1 or 2, in which the periodic movement consists of a combination of a displacement of the profile (1) in relation to the flow duct (12) and of a rotation of the profile (1) about an axis of rotation (14).

8.   The device as claimed in one of claims 1 to 7, which is followed on the flow medium side by a device for the destruction of vortices.

9.   A conveying zone for the transport of a flow medium (S), in the flow duct (12) of which is arranged a device as claimed in one of claims 1 to 8, which comprises a number of profiles (1) which execute a periodic movement with the same angular frequency ω and the same phase.

10.   A conveying zone for the transport of a flow medium (S), in the flow duct (12) of which is arranged a device as claimed in one of claims 1 to 8, which comprises a number of profiles (1) which execute a periodic movement with the same angular frequency ω and an opposite phase.

11.   An axial cascade for the throughflow of a flow medium (S), said cascade being preceded on the flow medium side by a device as claimed in one of claims 1 to 8, which comprises a number of profiles (1) which execute a periodic movement with the same angular frequency ω and the same phase.

12.   A cooling device for the cooling of components subjected to high thermal load, which comprises a flow duct (12), a cooling stream conducted through the flow

duct (12) and a device as claimed in one of claims 1 to
8 which is arranged within the flow duct (12).

13. A mixing zone for the mixing of one or more flow media (S) with one another, which comprises a flow duct (12) through which the flow media (S) are capable of flowing and a device as claimed in one of claims 1 to
5   8.

14. A gas turbine having a device as claimed in one of claims 1 to 13.

10 15. A method for the generation of vortices in a flow medium (S) by means of one or a number of profiles (1) arranged in a flow duct (12) and provided for flow around by the flow medium (S), the profiles (1) being moved periodically with the angular frequency ω by
15 means of an external drive.

16. The method as claimed in claim 15, in which the direction of energy transmission between moved profile (1) and flow medium (S) is set via the quotient of the
20 flow velocity averaged over a movement period of the profile (1) with respect to the mean cross section of the profile (1) and the maximum flow velocity at the trailing edge (4) of the profile (1).

25 17. The method as claimed in claim 15, in which the direction of energy transmission between profile (1) and flow medium (S) is set via the product of the maximum flow velocity at the trailing edge (4) of the profile (1) and of the elongation of the flow-around
30 profile (1), divided by the kinematic viscosity of the flow medium (S).

18. The method as claimed in one of claims 15 to 17, in which the generated vortices are completely or
35 partially destroyed again downstream of the position in the flow duct (12) at which they were generated.

19. The method as claimed in one of claims 15 to 18, which is used for the transport of a flow medium (S) through a flow duct (12).

5 20. The method as claimed in one of claims 15 to 18, which is used for increasing the efficiency of a cascade flow of the flow medium (S) through a cascade arranged within the flow duct (12).

10 21. The method as claimed in one of claims 15 to 18, which is used for the cooling of components subjected to high thermal load by means of a flow medium (S).

22. The method as claimed in one of claims 15 to 18, 15 which is used for mixing one or more flow media (S) in a flow duct (12).